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PIPE HANDLING APPARATUS AND METHOD

FIELD AND BACKGROUND OF THE INVENTION

This invention relates to a method for introducing a tube into a borehole in the ground according to the introductory portion of claim 1. The invention further relates to methods for removing or retracting a tube from a borehole in the ground according to the introductory portions of claims 17 and 18 and to an installation for introducing a tube into a borehole in the ground according to the introductory portion of claim 19. Such an installation typically also serves the purpose of retracting a tube from a borehole in the ground.

Such methods and such an installation are known from practice for instance for inserting a production tube in a well for extracting oil or gas or for removing such a tube from a well, for instance in the course of maintenance to downhole devices. Such wells can also be used for other purposes, such as for the extraction of salt or geothermal energy. In the use of such a method and such an installation, tube parts are coupled through a screw coupling to the upper end of a tube reaching into the borehole. As the tube is introduced further into the ground, successive a tube parts, which can each be composed of one or more tube joints, are connected by screw couplings to the proximal end of the composed section of the tube end projecting from the ground until the tube has reached its final length. When the tube is removed this method is essentially reversed.

Introduction and removal of a tube in this manner is tedious and entails certain dangers. More in particular, operating in an area closely adjacent the well head entails handling problems because little space is available and the tube parts have to be connected and disconnected in a

generally vertical orientation, difficult access to the joint to be made or disconnected and dangers of fire, explosions and of injuries caused by manipulated heavy objects.

As an alternative, it is known to prefabricate a tube by welding the tube parts to each other and to wind the prefabricated tube onto a reel according as the length of the composed tube section formed from the tube parts increases with the addition of tube parts. The tube wound onto the reel is subsequently transported by road to the site where it is to be introduced into the ground. During insertion of the tube into the borehole, the reel is unwound. During retraction, the tube is wound back onto the reel.

A disadvantage of this method is that the tube parts needs to be deformed to a large extent to obtain a reel having a diameter small enough to be handled and transported. This has an adverse influence on the mechanical properties and the geometry of the tube parts and imposes stringent requirements on the quality of the material, which should be such that the material, after the considerable deformations, still reliably meets the technical requirements applying in installed condition.

SUMMARY OF THE INVENTION

It is an object of the invention to avoid, at least to a considerable extent, the drawbacks associated with the above methods and installations.

This object is achieved according to the present invention by carrying out a method for introducing a tube into a borehole in the lithosphere in accordance with claim 1. In conjunction with the removal or at least retraction of tubes from a well, this object is achieved by carrying out a method for removing or retracting a tube from a borehole in the ground in accordance with claim 17 or 18. The invention further provides an installation according to

claim 17 which is specifically adapted for carrying out such methods.

Since connecting tube parts or disconnecting tube parts from a tube, and hence also the associated storage and displacement of tube parts, occurs in each case at a horizontal distance from the well head or - if the tube is temporarily stored without disassembling - the tube parts are not disconnected at all, the need of carrying out the connecting or disconnecting operations at the well is obviated.

Further, the separate tube parts of which a tube is to be composed can be transported to a drilling site more easily and more efficiently than in a configuration wound up into a coil.

Another important advantage of advancing the tube into the well along a curved path is that the assembly and introduction of the tube does not require the use of a rig. Round tripping including the extraction an re-introduction of a tube into a well can be carried out without a rig as well. Therefore, a rig used for drilling can be removed earlier so that important cost savings can be made.

Nevertheless, compared to the known system of supplying the tube in wound form, plastic deformations of the tube material are at least substantially reduced, so that the requirements the tube material has to meet are less stringent.

Particularly advantageous elaborations of the invention are set forth in the dependent claims. Further objects, elaborations, effects and details of the invention appear from the following description, in which reference is made to the drawing.

BRIEF DESCRIPTION OF THE DRAWING

Fig. 1 is a schematic representation in side view of a first example of an installation for carrying out the method according to the invention;

Fig. 2 is a schematic representation in top plan view of a second example of an installation for carrying out the method according to the invention;

Fig. 3 is a schematic representation in side view of the installation according to Fig. 2;

Fig. 4 is a schematic representation in top plan view of a portion of a third example of an installation for carrying out the method according to the invention in a first operating condition;

Fig. 5 is a schematic representation in side view of the portion of the installation according to Fig. 4;

Fig. 6 is a schematic representation in top plan view of a larger portion of the installation according to Fig. 4 in a second operating condition; and

Fig. 7 is a schematic representation in side view of the portion of the installation according to Fig. 6.

DETAILED DESCRIPTION

Although the exemplary elaborations discussed below generally relate to composing and inserting a tube into a borehole in the ground, these eleborations can also be applied in reverse direction for removing or at least retracting a tube from a borehole in the ground.

Fig. 1 shows a well 1 and a tube 2 which is being composed and introduced into the well 1. The tube 2 is made up of interconnected tube parts 8. The tube 2 extends both inside and outside the bored well 1. Outside the well 1, the tube 2 is guided along a guide path with guides 4, 5. The guide path starts near a proximal end 10 of the tube 2, first extends horizontally through a passage 15 and then, via smooth arcs, merges into a vertical portion in line with the borehole 1, where a lead-in device 3 - which serves to retain the tube axially and in a sense of rotation - engages the tube. The guides 4, 5 are provided with rollers over which the tube 2 can roll in axial direction. Preferably,

the rollers are steerable castoring wheels, so that the rollers can accommodate to any rotation of the tube 2.

Owing to the bent course of the guide path, the proximal end 10 of the tube 2 is located outside the line of the bored well 1. The guides 4, 5 provide that the proximal end 10 of the tube 2 is oriented substantially horizontally in the area of a connecting device 6 for successively adding a tube part to the proximal end 10.

The geometry of the path along which the tube 2 passes is such that the tube 2 is plastically deformed to a slight extent. The maximum deformation of the tube in the curves of the path is preferably less than 2% and more preferably less than 1%. Such small plastic deformations have relatively little adverse effect on the mechanical properties of the tube 2, even without the use of special steel alloys having improved resistance to fatigue and deformations. It is noted that the plastic deformation of the tube in the area where it enters a curved section of the path can be utilized with particular advantage for installing production tube, which is generally not rotated about its axis when being introduced.

If a tube which is deformed plastically in a curved axial feeding path between a jointing position and the well is to be rotated about the axis of the well, the composed tube is preferably stored in composed condition in the form of a coil (as is described in further detail below) and the coil as a whole is preferably rotated about the axis of the bore hole in the vicinity of the well head.

To achieve the desired limitation of the deformation of the material of the tube, the radius of each bend in the path of the tube 2 should be sufficiently large. For instance steel tubes having a 55 mm outer diameter, which are typically used in oil extraction, can be bent to a curve having a 2.75 m radius if a deformation of 1% is allowed. For comparison: if the deformation of the same type of tube is limited to 0.16 %, so that only elastic deformation occurs, a radius of 18 m is the smallest allowable radius.

Thus, by allowing some plastic deformation of the tube as it travels along the curved path section, a curved path section of a considerably smaller radius can be employed than if deformations are limited to elastic deformation. Accordingly, the amount of space required at the well site and the required size of the transport structure can be kept substantially more limited than if only elastic deformation is allowed. However, since the radius does not have to be as small as in tubing which is transported in coiled condition, the deformation can be kept sufficiently small to avoid the need of specifically adapted materials, in particular special kinds of steel, to ensure that the tube after placement satisfies the requirements set.

A further advantage of the plastic deformation of the tube is that the tube is easier to guide in the curved path section, since the curvature of the tube substantially defines the curves of the path along which the tube travels axially. Moreover, in the event of accidental release of the curved portion of the tube, a tube which is plastically bent into a curved path tends to spring back at least substantially less than a tube which is elastically deformed into a curved path, and is therefore much safer.

By means of the connecting device 6, the tube 2 can be extended by a next tube part or tube section 8. Such tubes sections 8 are present in a storage 11, where these tube sections 8, in this example, are stored horizontally and parallel to an end portion of the tube that connects to the proximal end 10 of the tube 2.

For extending the tube 2 by a next tube part, a tube part 8 is taken from the storage 11 and supplied to the connecting device 6 by means of a conveyor 7. The connecting device 6 is provided in the form of a mechanized welding machine. Such devices are commercially available and therefore not further described here. The proximal end 10 of the tube 2 is also located in the welding machine 6.

By each time welding a tube part to a proximal end 10 of the tube 2, very reliably sealed connections between the

tube parts 8 are obtained. Moreover, such welded connections form considerably smaller thickenings of the tube than, for instance, the known screw connections, or even do not form a thickening of significance at all.

Since the tube is composed from the tube parts at the well site, the composed tube does not have to be transported. Therefore, the curvature in the tube can have a greater radius than if the tube needs to be transported in coiled condition. As has been explained hereinbefore, a relatively great radius is advantageous because the plastic deformation then remains limited so that the requirements the tube material has to meet to ensure that the tube material can withstand such deformations and then still meet the requirements imposed by the operating conditions in the well are less stringent.

By virtue of the form in which the tube 2 is held by the guides 4, 5, the proximal end 10 of the tube 2 is remote from the bored well 1. As the provision of a next tube part 8 occurs at a horizontal distance from the well head, the jointing and associated manipulation of the tube parts 8 can take place at a location which is much easier accessible, where more space is available and where there is less risk of injury due to large moving parts. It is noted that this effect is also of advantage if the connection between the tube and a tube part to be added is obtained in a different manner than through welding. In the making of the connections by welding, however, a suitable location and orientation of the tube parts to be connected are of particular importance.

Particularly in the case of boreholes where oil and/or gas may be found, an area around the well head 13 involves a risk of fire and explosions. By carrying out the jointing operations at a distance from the well head 13, they can be carried out outside the area involving a particularly great risk of fire and explosion. It is noted that generally, to achieve this effect, it is required that the tube is closed off between the well and the proximal end of the tube in the

connecting area. This can for instance be achieved using a plug mounted on a rod or a cable extending into the tube, which plug is retained in a position closing off the tube in a position axially spaced from the end of the tube in the connecting area.

Further, the space 12 where welding occurs is screened off from the drilling environment and the outside climate by a shell 14, so that the risk of fire and explosions is further reduced. The horizontal distance between the well head 13 and the place where welding occurs is preferably at least 10 m and more preferably at least 15 to 17 m.

In the exemplary embodiment according to Fig. 1, the tube parts 8 are added to the tube 2 in a horizontal orientation relative to the bored well. However, other orientations remote from the bored well can also be used, such as, for instance, parallel to the bored well or at an oblique angle relative to the bored well. A horizontal orientation of the tube parts 8 in the area where they are added to the tube 2 provides the advantage that standard machines for joining tubes together can be used in their normal orientation.

The welding machine 6 welds a tube part 8 to the tube 2 each time when the proximal end 10 of the tube 2 has reached the welding zone of the welding machine 6. Consequently, the tube 2 is each time extended by the length of the tube part 8.

Thereupon, the tube 2 is displaced over the length of the tube part 8 just added, along the above-described path, whereby the tube 2 is inserted deeper into the bored well 1. To that end, the lead-in device 3 is set into operation.

If the lead-in device 3 is further arranged for rotating the tube 2, the tube 2 is rotated in the hole 1, and the portion of the tube 2 that projects outside the borehole 1 is rotated about its axis as well, it is advantageous if the tube 2 in the area of the guides 4, 5, where the axis of the tube 2 is curved, is exclusively elastically deformed with respect to the straight initial

form in which the tube parts are supplied. The repeated deformation occurring during rotation, of the portion of the tube 2 that curves through the guide 4, 5 then remains without essential disadvantageous consequences for the loadability and the shape of the tube parts 8 in question, although after prolonged flexing of the same portion of tubing, fatigue can cause problems. Axial rotation of the tube 2 is particularly advantageous during the drilling of a well or the insertion of a wall, a so-called casing, in the bored well.

Although the present example is based on a single tube, the invention is also applicable in the case of the insertion of a tube composed of concentric tubes. It is then preferred not to deform the tube plastically. The different concentric tube parts can be provided one after the other in the bored well, or be installed simultaneously.

Sub B1 ~~Connecting the tube parts 8 to each other by welding can be applied with particular advantage when inserting tubes into a well with an overpressure prevailing under a sealing 16 at the upper end of the well, a situation sometimes referred to as "underbalanced". Since the welded tube 2 has a much more constant outside diameter than a tube composed of tube parts screwed together, the borehole 1 adjacent the well head 1 can be better sealed by means of a sealing, such as, for instance, a blow-out preventer. It is then especially of importance that the sealing 16 against the tube 2, when it is being passed by connections between tube parts 8, needs to bridge considerably smaller differences in diameter than is the case in the use of a tube composed of parts screwed together.~~

The installation shown in Fig. 1 can also be used for removing or retracting the tube 2 from the well 1. Depending on the situation of the well site, the tube 2 can be decomposed at the welding machine, for instance by cutting or by disconnecting couplings included in the tube for this purpose, or be left intact and extended along the ground. If the tube is decomposed into sections, the sections can for

instance be of the size of the original tube parts or of a larger size.

Figs. 2 and 3 represent an exemplary embodiment of the invention with which likewise a tube 52 is introduced via a well head 63 into a bored well. The tube 52 is made up of tube parts 58 joined together. Outside the bored well, the tube 52 extends along a path which, starting from a proximal end 60 of the tube 52 towards the well head 63, first extends approximately horizontally, and then passes via an arc, bent over 270°, to merge into a vertical part in line with the borehole, where a lead-in device 53 engages the tube 52.

Between the approximately horizontal portion and the portion located in line with the borehole, the tube 52 is bent exclusively in one direction relative to the portions in question of the tube 52. This means that if a particular tube section moves through the curved path section 69, it is bent to a curve just a single time and in a single direction, and it is straightened only once and in a single direction. Thus, each portion of the tube, as it travels from the horizontal path section to the path section projecting into the ground or back, is bent only once and bent back only once during each trip of composing and inserting a string of tubing into the well. The same applies, but in the opposite direction, if the tube 52 is removed or retracted from the well. Deterioration of the mechanical properties of the material of the tube 52 as a result of plastic deformation of the tube 52 is thereby limited.

That each plastically bent portion of the tube 52, as it leaves the curved path section 69, is bent back again, provides the advantage that the tube 52 fits into the substantially straight borehole without the deformations applied upon entry of the curved path section 69 leading to great transverse forces between the tube and the wall of the borehole.

Here, too, the radius of the curved path section 69 of the tube 52 is such that the tube 52 is plastically deformed to a slight extent only, so that the mechanical properties of the tube 52 suffer little, if noticeable at all, and a tube 52 can be introduced into and removed from a well a large number of times.

For adding tube parts 58 to the tube 52, the installation is provided with a welding machine 56. For supplying tube parts 58 to be added, the installation is provided with a roller path 57 with a transport roller pair 70 at an end thereof.

Downstream of the welding machine 56, a transport roller pair 71 forms an upstream end of a conveyor 72 which extends to a bending machine 67.

Also in the use of the installation according to Figs. 2 and 3, the form of the tube 52 downstream of the welding machine 56 provides that the proximal end 60 of the tube 52 is located at a distance from the well head 63.

The bending machine 67 also directs the axially traveling tube 52 via the curved path section 69 shown. The installation is provided with a further machine 68 for bending back the tube material, which may be formed by yet another bending machine or by a straightening machine. Straightening machines typically have more rollers than bending machines. The first (as viewed in the direction of transport) tube bending machine 67 bends the tube 52 to a curve as the tube 52 is passed axially through the bending machine 67. The curvature applied by the bending machine preferably has a slightly greater radius than that which is needed to reach the bending-back machine 68 via the arc 69. Accordingly, some additional bending is needed to reach the bending-back machine 68. This is obtained by elastic deformation of the tube 52. By combining plastic and elastic deformation of the tube 52 to obtain a curved shape, less plastic deformation is needed than if the same curved shape is obtained by plastic deformation only, so that less force is needed to bend the tube to a curve, and a substantially

reduced mechanical deterioration of the material is obtained.

For leading-in a leading portion of a new tube 52, and thereby, through elastic bending, rendering it more curved than the curvature applied by the bending machine 67, the leading portion can be coupled to a cable which is pulled in by the bending-back machine 68 and which pulls the leading end of a tube to the well head 63. Instead of by using a bending machine, the bending of the tube into the curved path section 69 can also be achieved solely by guiding the leading portion from the conveyor 72 to the feeding unit 53 for introducing the tube 52 into the well head 63, whereby the tube 52, as it travels along the curved path portion 69, is subject to a maximum elastic deformation and therefore, at a given bending radius, is subject to a minimal plastic deformation.

That the tube 52 is bent by a bending machine 67 as it enters the curved path section 69 provides the advantage that the curvature provided by the bending machine 67 also determines the further path of movement of the tube 52, at least to an important extent, so that between the point where the tube 52 is bent to a curve and the point where the tube 52 is bent straight again, no or very little guidance is needed and a relatively simple transport construction can be provided.

Figs. 4-7 represent portions of the same apparatus in two operating stages. Some parts of the installation that are not relevant to the differences between the above-discussed installations and that according to Figs. 4-7, such as the lead-in device for introducing the tube into the bored well and the machine for adding tube parts to the tube, are not shown in Figs. 4-7. In the first stage (Figs. 4 and 5), the tube 102 is supplied in a supply direction indicated by an arrow 123, from a welding machine in which a tube part has been, and is, added to the tube 102 as the proximal end of the tube (not shown) reaches the welding machine upon displacement of the tube 102 in the

direction indicated by the arrow 123. Upon reaching the bending machine 117, the tube is plastically deformed to a curved form and passed along an approximately circular path along supporting rollers 124, 125, which are suspended from a frame 126 before and behind (as viewed in the supply direction 123) the bending machine 117, for rotation about their longitudinal axes. As more tube material is supplied, a spiral and essentially helical curl of tube material is formed, which is supported on and between the rollers 124, 125. When the tube 102 has reached the required length, or when the rollers cannot carry more tube material, the supply of tube material is stopped.

As is represented in Figs. 6 and 7, the frame 126 with the rollers 124, 125 for temporarily storing a tube 102 formed and wound into a helical form at the well head 113 is arranged so close to the well head that material of the tube 102 can be unwound from the helical configuration and be axially transported further via an arcuate path in a direction indicated by an arrow 127 to the well head 113.

To be able to unwind the tube 102, the bending machine 117 is displaceable to a position 117' along a portion of the tube 102 which is located on the side of the helically rolled-up tube 102 remote from the well head. In the position 117', the bending machine is set for reducing the bend of the tube 102 as it passes the bending machine 117', so that the tube 102 departs from the helical form 128, and via an arc 129 with a radius greater than that of tube material in the helical portion 128 of the tube 102, moves axially to a bending machine 130 in line with the well head 113 which further straightens the tube.

By completing the composition of the tube or at least a section of the tube before bringing the tube into the well the insertion of the tube can be carried out very rapidly as soon as the bored well has been cleared for insertion of the tube 102, because insertion is not delayed by the necessity of adding a tube part every time. Conversely, composing the tube is not delayed in that the transport speed of each

added tube part is limited by the maximum insertion speed of a tube. Further, the logistic planning of the composition and insertion of a tube is simplified because personnel and equipment for composing the tube do not necessarily need to be available at the actual time of insertion. Thus, by at least partially carrying out the on-site composition of the tube before the well into which it has to be inserted is ready for receiving the tube, substantial time gains can be achieved.

Owing to the coiled form in which the tube is temporarily stored, the tube 102 can nonetheless be held ready in a compact space before being introduced. However, at sites where sufficient space is available (for instance in a remote dessert area or at a location where a length of unused road or railroad is available) the pre-composed tube or tube sections can also be stored as a length of tubing extending along the ground as was described in conjunction with Fig. 1.

If a string of tubing is subsequently retracted from the well and stored in a coiled configuration, it can even be retracted and re-inserted without being bent more than once and without being bent back more than once. So that deterioration of material properties due to deformation thereof is kept very limited.

Compared with the transportation to the site of a tube in a coiled form, the advantage is maintained that radius of curvature of the tube can be relatively large, so that less stringent requirements are imposed on the material of the tube.

Another advantage of completing the composition of the tube or at least a section of the tube before bringing the tube in communication with the well is, that the risk of fire and explosions is particularly reduced. Since the tube being composed is not connected to the well while it is composed, it does not need to be closed off to avoid that the channel in the tube is in communication with the well causing the hazard area where a particular risk of explosion

and fire exists to extend to the free end of the tube projecting from the well.

Yet another advantage of completing the composition of the tube or at least a section of the tube before bringing the tube in communication with the well is, that the entire tube or tube section can be tested for leaks and pressure resistance before being introduced into the well.

There are various options for the precise setting of the bending machines 117' and 130 in the unwinding of the tube 102 from the helical form 128.

It is, for instance, possible to set the bending-back machine 117' such that it bends the tube 102 just straight as it passes that machine 117'. The radius of the arcuate path portion 129 should then be preferably selected so great that the tube portions just bent straight again are exclusively deformed elastically as they follow the arcuate path section 129. The bending-back machine 130 downstream of the bending-back machine 117' then runs along passively without deforming the tube 102 further, and may optionally be replaced with a guide roller.

It is also possible not to deform the tube plastically at all at the bending-back machine 117' and to have the plastic deformation back to the straight initial form occur solely when the tube passes the bending machine 130 with an exit in line with the well head 113. In that case, the radius of the arcuate path section 129 is then preferably chosen to be so small that the tube 102, as it follows the arcuate path section 129 starting from the form in which it was disposed in the helical portion 128 of the tube 102, is not deformed or deformed elastically only. The bending-back machine 117' upstream of the bending-back machine 130 then idles passively without deforming the tube 102 and may optionally be replaced with guide rollers. In that case, it is advantageous to provide that the bending machine 117 is displaceable to a position in which the exit thereof is in line with the well head - in this example the position of the bending-back machine 130.

It is also possible to opt for a middle road between these two settings, whereby the tube 102, when being unwound from the helical form, is bent back into a form which is straight in unloaded condition, in two operations, i.e. at the location of the bending machines 117' and 130, respectively.

The provision of an arc shaped curved section 129 between the coil and the well, which curved section 129 has a larger radius than the coil provides the advantage that the coil can be located over some horizontal distance spaced away from the well 113. This horizontal distance is largest if the curved section with the enlarged radius departs form the portion of the tube 102 with the smaller arc in a vertically upward direction. However, it is also possible to provide that, instead of the position 117', the alternative position of the bending machine 117 is elsewhere along the portion of the tube 102 with the smaller arc, for instance lower or even at the position of the bending machine 117. In the latter case, if the small and enlarged radiuses are identical, the horizontal distance between the portion of the tube 102 with the smaller arc and the well 113 is about half the distance in the example as shown in Fig. 7.

It is also possible to arrange the coil in such a position, that the axis of the well tangentially meets the coil and to provide that the straightening device is located with its operative part substantially in line with the well also. The tube portions unwound in a downward direction from the coil can then be lead into the well directly and vertically downward while in an essentially straight form.

It will be clear to those skilled in the art that within the scope of the invention, many alternative modes and designs are possible, different from the examples described hereinabove.

By way of non-limiting example, it can be mentioned, for instance, that for leading-in the leading end of a tube, many different facilities can be utilized, such as a cable

or a system of run-in guides in stationary positions along the intended path of a tube. Facilities for supporting the tube wound into a helical form can be designed in different ways, for instance with a roller for supporting the tube in the upper area of the helical form and/or with facilities for keeping the tube in the helical form under an elastic bias, so that the tube needs to be deformed plastically only to a relatively slight extent to obtain a helical form of a certain diameter. Instead of, or supplemental to, a helical form, the wound tube can also have a spiral form, so that the tube can be wound in several coaxial layers. Furthermore, the tube can form a section of a larger tube assembly composed or to be composed of two or more of such tubes which are for instance each composed and then stored separately in a helical or spiral configuration. After a first tube is introduced into the well, a next tube is connected thereto and then the first tube is inserted deeper into the well with the connected next tube following the first tube into the well.